BELLCOMM, INC.

SUBJECT: Accumulation of Momentum and CMG Loading for Two Cluster Configurations - Case 600-3

DATE: May 15, 1967

FROM: C. O. Guffee

ABSTRACT

This memorandum describes the general form of momentum accumulation during an out of plane, ATM pointing experiment. Holding the principal axis of inertia, in the direction of the ATM, inclined to the orbital plane results in an accumulation of bias momentum with increasing time in orbit. This will eventually cause the CMG's to saturate and require the use of a desaturation scheme. The accumulation of momentum for two cluster configurations is described, and an indication is given of the number of orbits obtainable before the CMG's saturate.

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(NASA-CR-154377) ACCUMULATION OF MOMENTUM AND CMG LOADING FOR TWO CLUSTER CONFIGURATIONS (Bellcomm, Inc.) 7 p

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MEMORANDUM FOR FILE

The accumulation of momentum and its effect upon how often the CMG's must be unloaded is presently under study for the cluster configuration. Two distinct configurations are being studied.

Configuration I: LM-ATM docked on side port of MDA, CSM docked on axial port.

Configuration II: LM-ATM docked on side port of MDA, CSM docked on a perpendicular side port.

The spacecraft axes associated with each configuration are illustrated below. This study is concerned with the accumulation of momentum about the principal axes of inertia which are in the same general direction as the spacecraft axes.

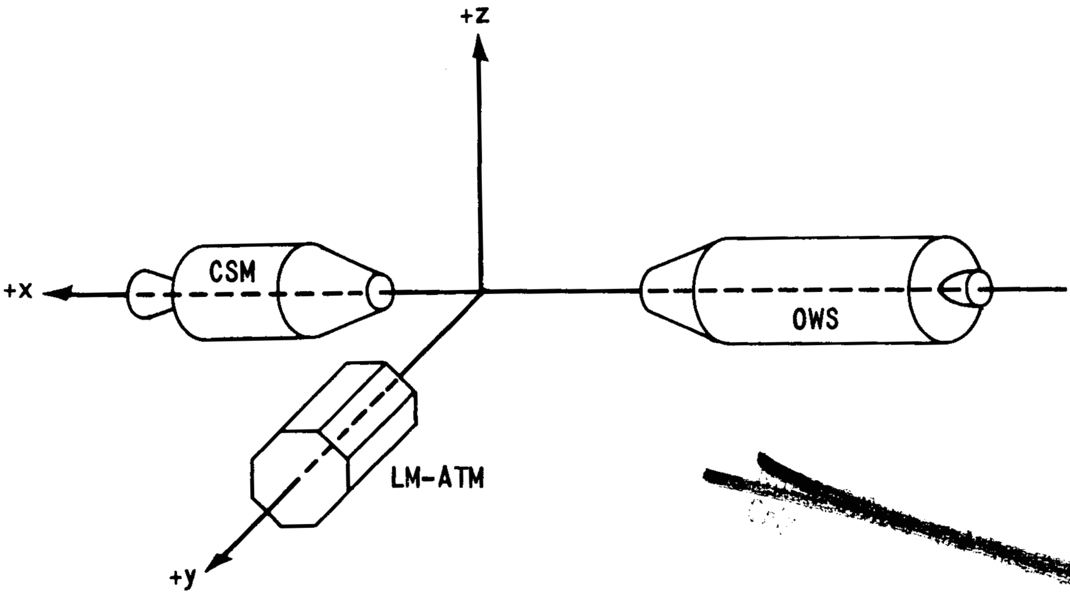

FIGURE I - CONFIGURATION I

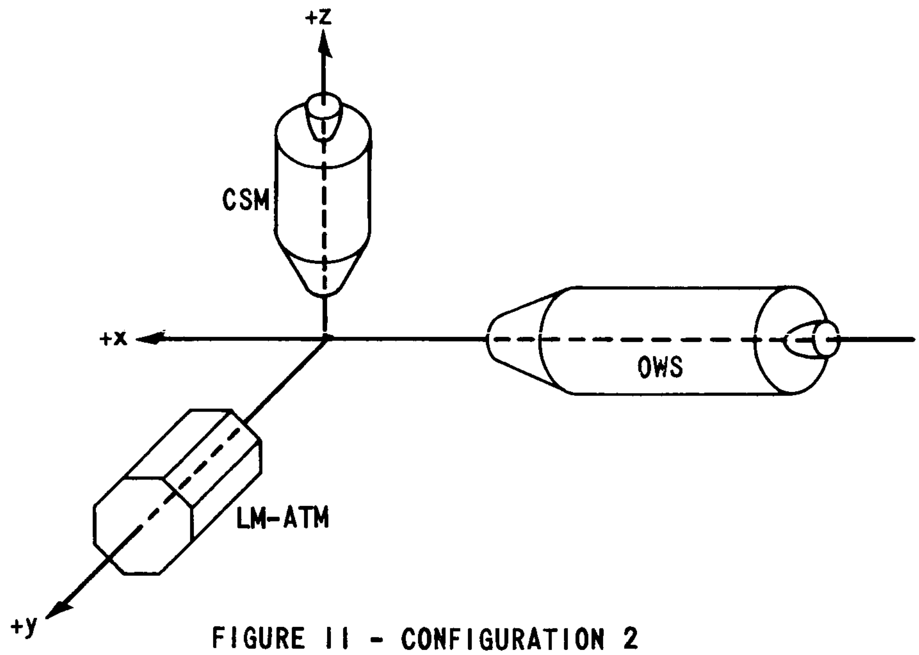

FIGURE II - CONFIGURATION 2

The principal moments of inertia associated with each configuration used in this study are listed in the following Table.

Table I - Principal Moments of Inertia

	CONFIGURATION I CSM ON AXIAL PORT	CONFIGURATION II CSM ON SIDE PORT
I_x (slugs-ft^2)	353.1×10^3	584.17×10^3
I_y (slugs-ft^2)	3016.64×10^3	2475.46×10^3
I_z (slugs-ft^2)	3193.59×10^3	2358.76×10^3

During the ATM experiments, the telescope axis will be oriented towards the sun, and the axis of minimum moment of inertia (principal x axis) will be held in the orbital plane. This orientation will result in a non-periodic accumulation of momentum about the principal x axis since I_y and I_z are not equal.

The rate of accumulation of momentum will be maximum when the principal y axis is forty-five degrees to the orbital plane. In this orientation, the time variation of momentum about each principal axis due to gravity gradient and aerodynamic torques is given by the following:

Configuration I

$$H_x\ (t) = -0.163\ t + 73.4\ \mathrm{SIN}\ (2\ \omega_o t)$$

$$H_y\ (t) = 1675 - 1675\ \mathrm{COS}\ (2\ \omega_o t) - \alpha * 5260\ \mathrm{SIN}\ (\omega_o t)$$

$$H_z\ (t) = 1570 - 1570\ \mathrm{COS}\ (2\ \omega_o t) - \alpha * 4930\ \mathrm{SIN}\ (\omega_o t)$$

Configuration II

$$H_x\ (t) = 0.109\ t - 48.6\ \mathrm{SIN}\ (2\ \omega_o t)$$

$$H_y\ (t) = 1045 - 1045\ \mathrm{COS}\ (2\ \omega_o t) - \alpha * 3285\ \mathrm{SIN}\ (\omega_o t)$$

$$H_z\ (t) = 1114 - 1090\ \mathrm{COS}\ (2\ \omega_o t) - \alpha * 3500\ \mathrm{SIN}\ (\omega_o t)$$

In the above expressions, ω_o is the orbital rate and is 1.11×10^{-3} radians/second (period is 5654 seconds) for a 260 n. mile circular orbit. The periodic terms which vary at the orbital rate ω_o are due to aerodynamic torques, while the remainder of the terms are due to gravity gradient torque. The constant α is the ratio of peak aerodynamic torque to peak gravity gradient torque.

Figure III is a plot of the magnitude of the accumulated momentum, during the first two orbits, for Configuration I. For zero aerodynamic torque, the accumulated momentum can be approximated by a periodic function, varying at twice the orbital rate, riding on a monotonically increasing function of time. The effect of aerodynamic torque is to reduce one of the peaks while increasing the other peak of periodic function due to gravity gradient torque. This is illustrated in Figure III.

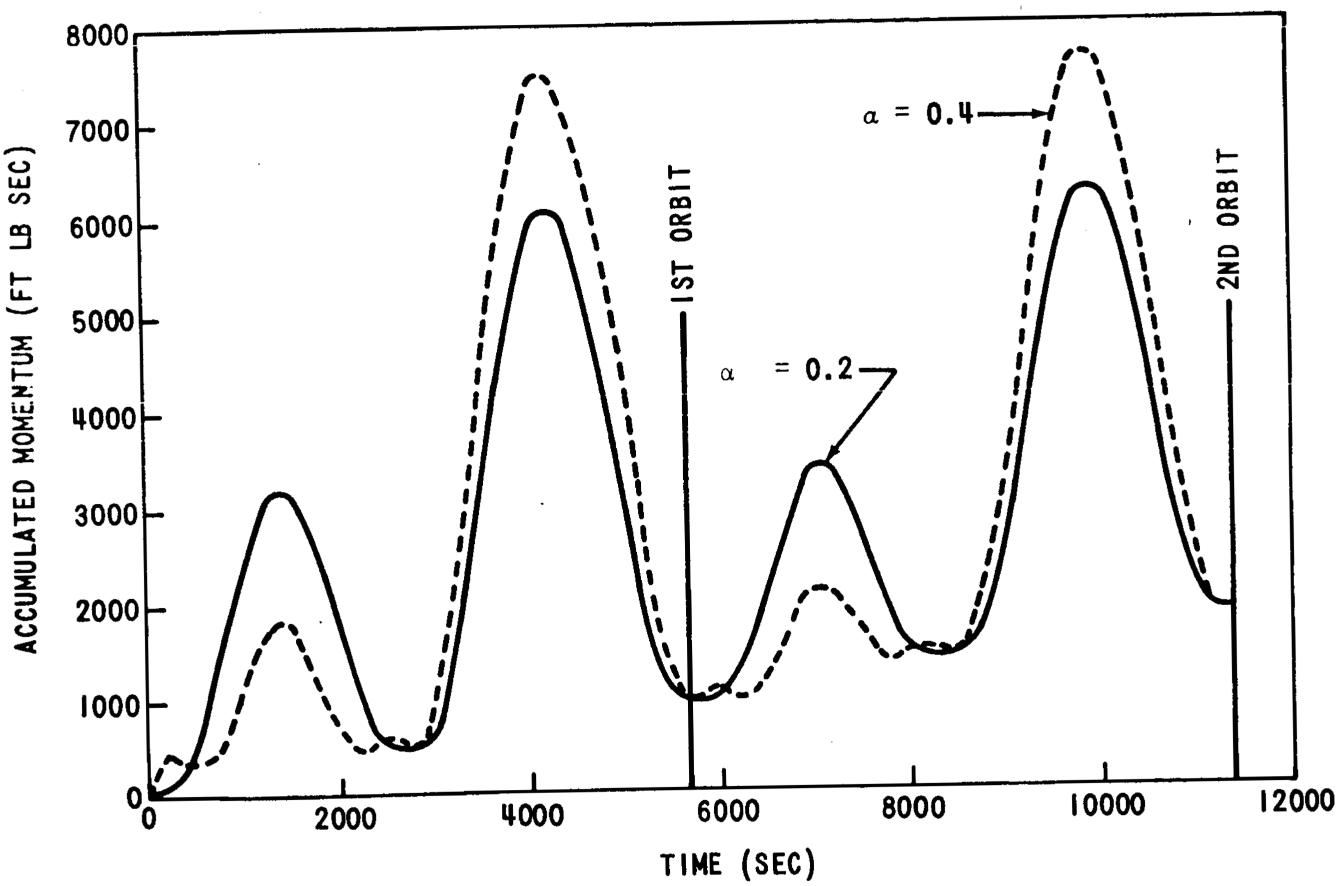

FIGURE III - ACCUMULATED MOMENTUM FOR CONFIGURATION I

Figure IV is a plot of the peak value of accumulated momentum for successive orbits for each configuration. Knowing the maximum momentum which can be accumulated by the CMG's, Figure IV can be used to determine the number of full orbits which can be obtained before CMG saturation occurs. For example, if the CMG system can accumulate 11000 ft lb sec of momentum, then Configuration I with α = 0.4 can achieve eight full orbits before CMG saturation occurs.

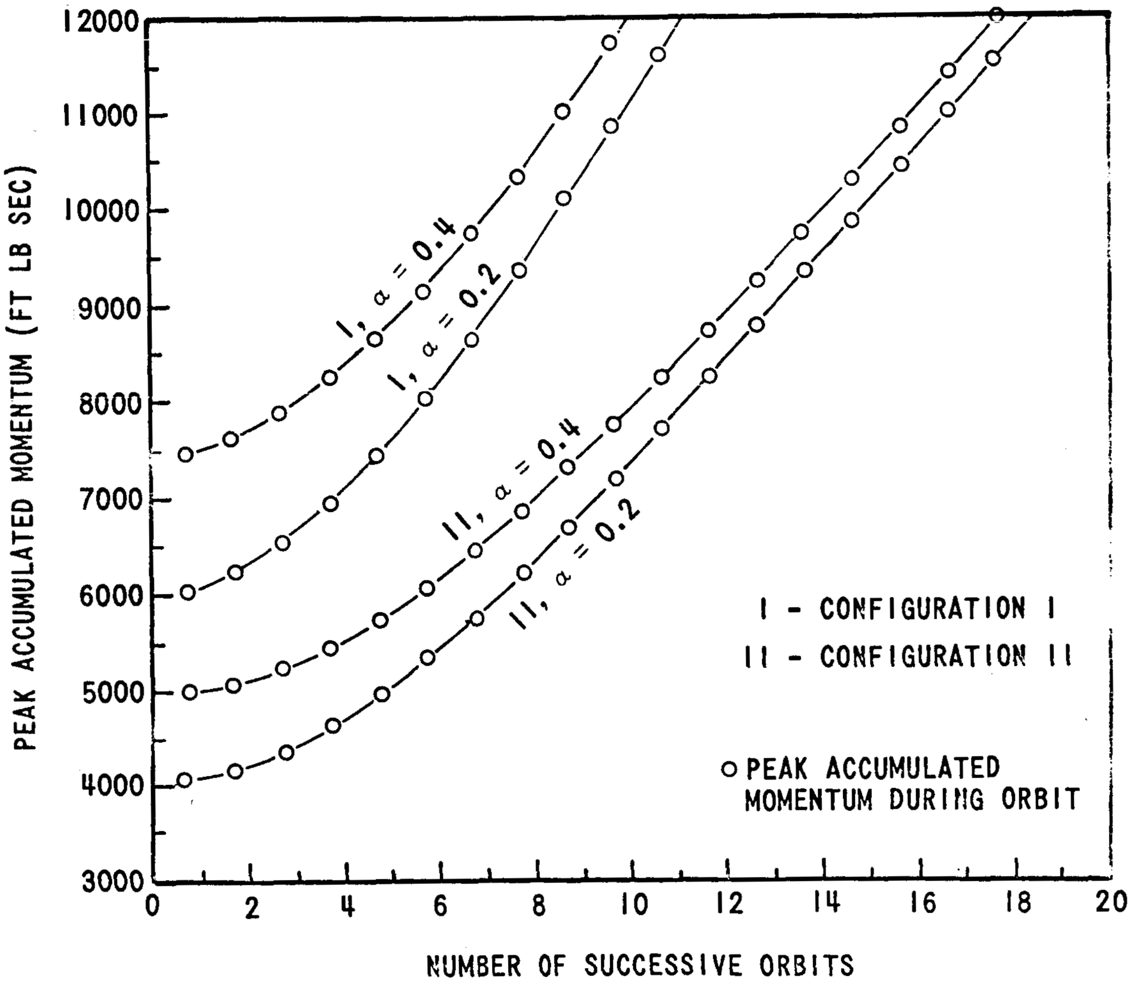

FIGURE IV - PEAK ACCUMULATED MOMENTUM VS NUMBER OF SUCCESSIVE ORBITS

Several points must be clarified about the above example and the use of Figure IV.

- The supposition that the CMG system can safely accumulate 11000 ft lb sec of momentum is based upon the assumptions that an optimal initial orientation of the CMG spin vector is obtained, and that the CMG gimbal angle limits are not exceeded as the disturbing torques are being counteracted.

- In actual practice it is necessary to leave some margin for momentum accumulation by the CMG, thus in the above example the CMG system could be unloaded after five orbits rather than attempting to obtain the full eight orbits.

- Figure IV is for the worst case of accumulated momentum about the x axis, i.e., the principal y axis is forty-five degrees to the orbital plane.

Study is being continued on the optimal initial orientation of the CMG spin axes and the impact of gimbal angle limits.

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From: C. O. Guffee

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